# Correlations of Power-law Spectral and QPO Features In Black Hole Candidate Sources

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Recent studies have shown that strong correlations are observed between low frequency QPO's and the spectral power law index for a number of black hole candidate sources (BHC's), when these sources exhibit quasi-steady hard x-ray emission states. The dominant long standing interpretation of QPO's is that they are produced in and are the signature of the thermal accretion disk. Paradoxically, strong QPO's are present even in the cases where the thermal component is negligible. We present a model which identifies the origin of the QPO's and relates them directly to the properties of a compact coronal region which is bounded by the adjustment from Keplerian to sub-Kelperian inflow into the BH and which is primarily responsible for the observed power law spectrum. The model also predicts the relationship between high and low frequency QPO's and shows how BH's can be unique identified from observations of the soft states of NS's and BHC's.

## §1. Introduction

A number of observations of BHC's do not show consistent correlations of low QPO frequency with disk parameters [1,2]. On the other hand, strong consistent correlations between power law spectral index and low frequency QPO's have been recently observed [3]. In addition, there is mounting observational evidence that the large number of spectral "states" formerly developed by to explain the wide variability of BHC's such as GRS1915+105, can be reduced to a few canonical states, i.e. a hard state with spectral power law index $\Gamma \sim 1.6 \pm 0.1$ , a soft or "extended" power-law state characterized by $\Gamma \sim 2.7 \pm 0.2$, and a thermal state [4].

These data have prompted us to introduce a model, i.e. the Transition Layer (TL) model [5] to explain the correlations observed. The main feature of the TL model is a hot compact region near the BH which serves as the primary region for Compton upscattering of soft disk photons. The TL model shows how the QPO's are related to the size, optical depth, temperature and spectral index and predicts the correlation between index and QPO frequency.

## §2. Predictions of the Model

The model predicts two generic classes or states for accreting BH's:

*HARD STATE*: In this state the energy release in the outer boundary of the corona $Q_{cor}$ is much greater than the energy release in the disk $Q_d$ ($Q_{cor} \gg Q_d$). Also: a) the mass accretion rate in the disk $\dot{m} = \dot{M}/\dot{M}_{\rm Edd}$ is small, b) the optical depth of the corona is order of unity and at least few times larger than the mass accretion rate in the disk $\dot{m}$, c) the Compton $y$ parameter in the hard state is almost a universal constant and is independent of $Q_d$ ; this leads to a universal value of the

photon index $\Gamma \sim 1.6 \pm 0.1$, and d) the efficiency for photon upscattering is second order in $V/c$, where V is the mean plasma thermal velocity (thermal Comptonization regime).

*SOFT STATE*: In this state the opposite condition applies, i.e. $Q_{cor} << Q_d$. As the mass accretion rate increases the system goes to soft state and the photon index saturates to an asymptotic value $\Gamma = 2.7 \pm 0.2$ depending on the temperature of the flow, which is of the order of the photon disk temperature (1-10 keV). The efficiency for upscattering is determined by first order in $V/c$ ( bulk inflow Comptonization regime).

The QPO low frequency $\nu_{low}$ is associated with the magnetoacoustic oscillation of the transition layer (cavity) i.e. $\nu_{low} \sim V/L$ ; where $L$ is a cavity size. The QPO high frequency $\nu_{high}$ is related to the Keplerian frequency at the outer TL boundary radius.

## §3. Data Interpretation and Summary

A fit to the data (Fig.1) is obtained from analytical relationships [6] associating: 1) the Reynolds number $\gamma$ for the accretion flow, which is a function of the mass accretion rate and the viscosity in the disk, and the size of the TL; 2) the optical depth, plasma temperature and spectral index of the TL; and 3)the QPO frequency and spectral index.

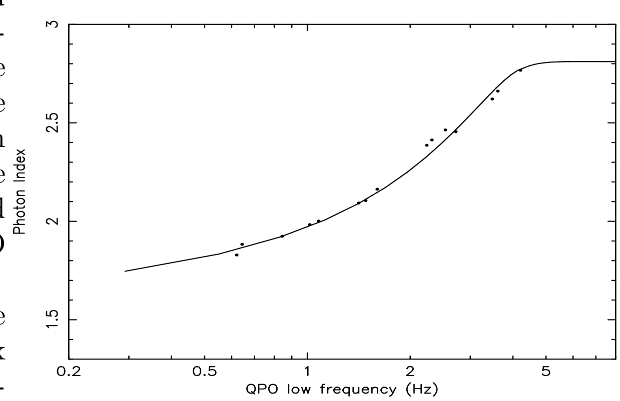


Fig. 1. Plot of power law photon index versus QPO centroid frequency for the plateau observations of GRS1915+105 from [3] along with a fit using the TL Model with $M = 12M_{\odot}$, $\tau_0 = \gamma^{1.25}$.

In contrast to BH's, NS's in the high/soft state do not show high index power-law spectra, but rather a blackbody like spectrum due to the presence of the surface and radiation pressure. Bulk inflow Comptonization present in the case of a BH is never present for NS's. Thus, the observed saturation of the QPO frequency with spectral indices of $\Gamma \sim 2.7$ is a unique signature of BH's and can be used to identify them.

**References**

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